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(54) **POSITIVE CRANKCASE VENTILATION SYSTEM**

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(51) **Int. Cl.**

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F01M 13/02	(2006.01)
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(52) **U.S. Cl.**

CPC ***F01M 13/04*** (2013.01); *F01M 2013/0438* (2013.01); *F01M 13/023* (2013.01); *F02M 25/06* (2013.01); *F01M 13/022* (2013.01)

(58) **Field of Classification Search**

CPC F01M 13/04; F01M 2013/0438; F01M 13/023; F01M 13/22; F02M 25/06

USPC 123/573

See application file for complete search history.

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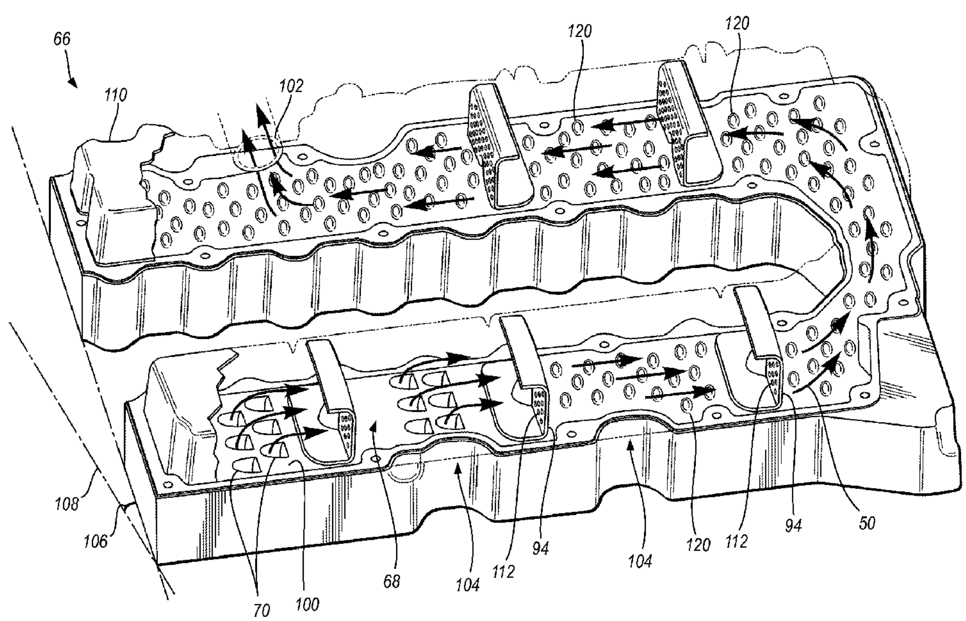
(57) **ABSTRACT**

An engine assembly includes an engine and an intake assembly. The engine defines a combustion chamber and a crankcase, and the intake assembly includes an intake manifold in fluid communication with the combustion chamber. An air-oil separator is provided with the engine and defines a separator volume, an inlet and an outlet, where each of the inlet and outlet are in fluid communication with the separator volume. The inlet of the air-oil separator is provided in fluid communication with the crankcase, and the outlet of the air-oil separator is provided in fluid communication with the intake manifold. The air-oil separator further includes an interior surface that abuts and surrounds the separator volume, and defines a plurality of depressions, and each depression is respectively configured to retain a respective volume of fluid.

20 Claims, 2 Drawing Sheets



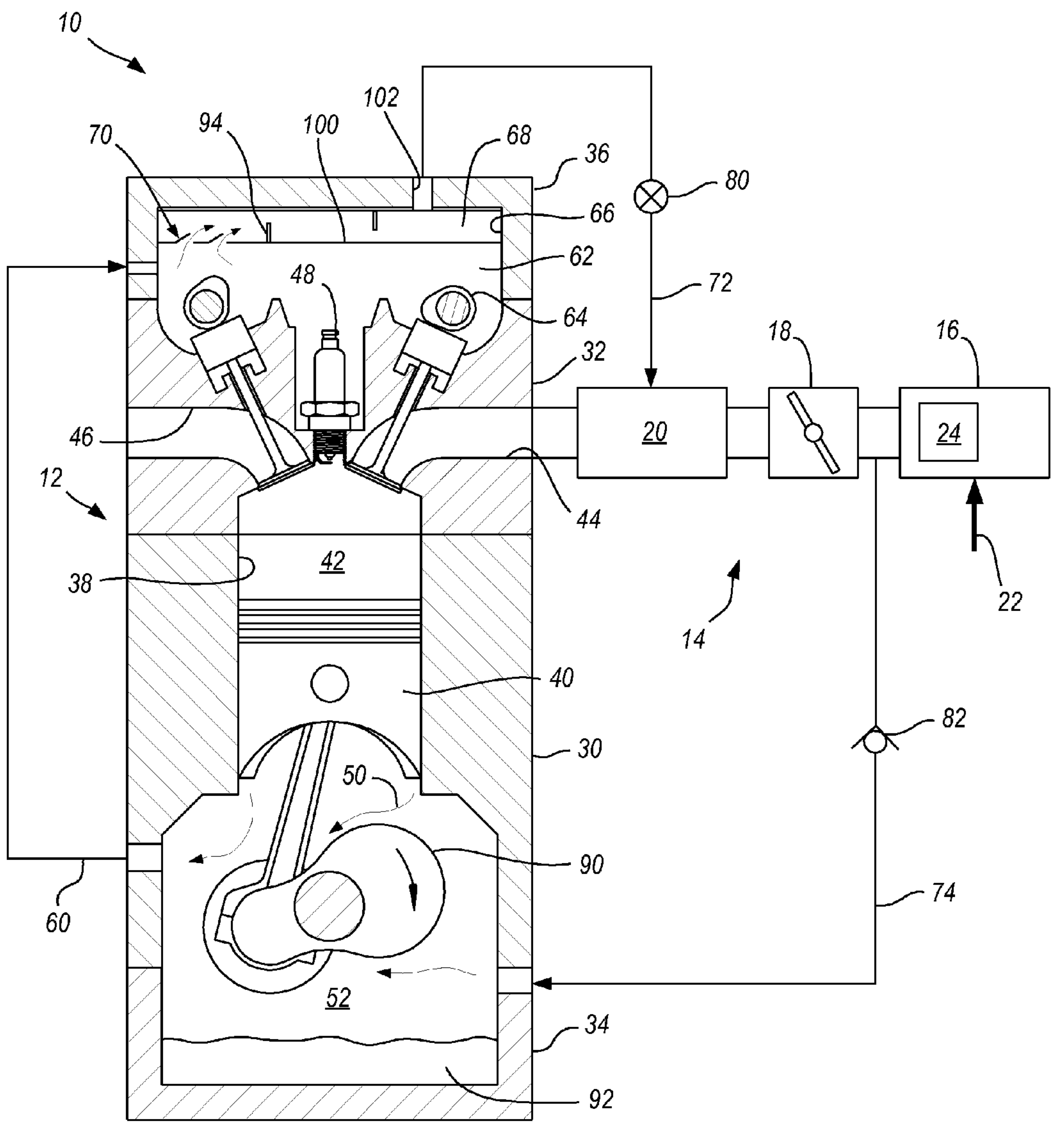

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FIG. 1

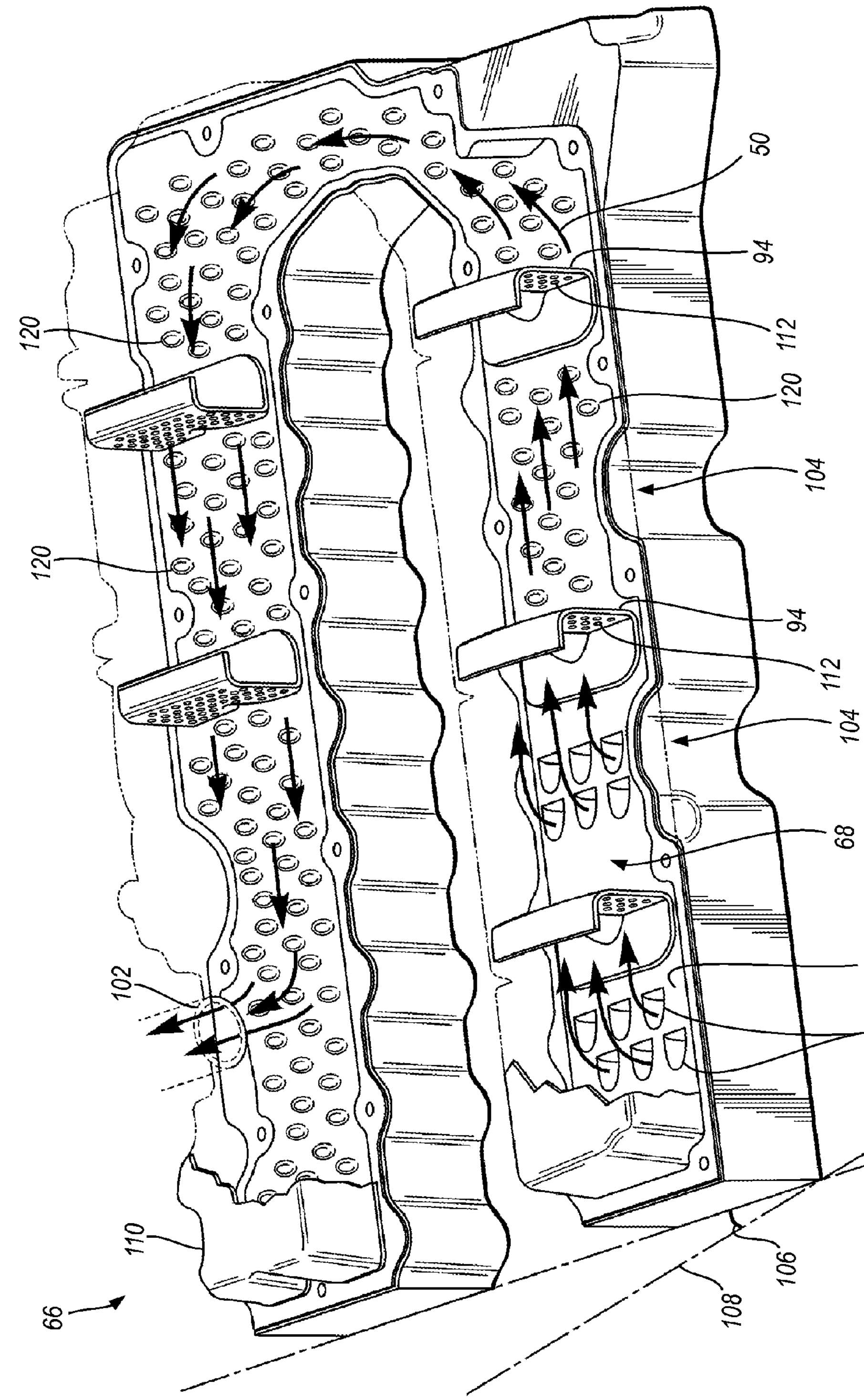

FIG. 2

POSITIVE CRANKCASE VENTILATION SYSTEM

TECHNICAL FIELD

The present invention relates generally to a positive crankcase ventilation system with an air-oil separator configured to extract oil from engine blowby gasses.

BACKGROUND

During engine operation, combustion gas may leak between the cylinder and the corresponding piston rings, and into the engine crankcase. The leaked combustion gas is referred to as blowby gas, and typically includes intake air, unburned fuel, exhaust gas, oil mist, and water vapor. In an effort to ventilate the crankcase and re-circulate the blowby gas to the intake side of the engine, a positive crankcase ventilation (PCV) system may be used.

SUMMARY

An engine assembly includes an engine and an intake assembly. The engine defines a combustion chamber and a crankcase, and the intake assembly includes an intake manifold in fluid communication with the combustion chamber. An air-oil separator may be provided with the engine and may define a separator volume, an inlet and an outlet, wherein each of the inlet and outlet are in fluid communication with the separator volume.

The inlet of the air-oil separator may be provided in fluid communication with the crankcase, and the outlet of the air-oil separator may be provided in fluid communication with the intake manifold. Likewise, the air-oil separator may further include a drain that may be configured to allow separated oil to return to the crankcase. In one configuration, the drain may be gravity fed.

The air-oil separator includes an interior surface that abuts and surrounds the separator volume. The interior surface defines a plurality of depressions, each being configured to retain a respective volume of fluid. Each of the plurality of depressions may be configured to restrain its respective volume of fluid from freely flowing to the drain. In this manner, the plurality of depressions maintain a minimum average surface wetness across the interior surface of the air-oil separator. Additionally, each of the plurality of depressions has an average diameter between 1 mm and 10 mm.

The air-oil separator may further include one or more baffles extending from the interior surface into the separator volume. Each baffle may define a plurality of holes that may aid in separating the aerosol oil particulate from the flowing air.

The engine may further include an engine block, a cylinder head, an oil pan, and a cylinder head cover, and the air-oil separator may be disposed within a volume partially defined by the cylinder head and cylinder head cover.

The intake assembly may include a throttle in communication with the intake manifold. The throttle may be configured to selectively control air flow into the intake manifold. Additionally, the intake assembly may include an air cleaner in fluid communication with and located upstream of the throttle.

In a similar manner, a method of separating oil from engine blowby gas may include: venting the blowby gas from the crankcase of an engine into an air-oil separator; flowing the blowby gas through a separator volume defined by the air-oil separator, the air-oil separator having an interior surface abutting and surrounding the separator volume; and venting the blowby gas from the separator volume into an intake manifold of the engine. As mentioned above, the interior surface of the air-oil separator may define a plurality of depressions, each being configured to retain a respective volume of fluid.

The above features and advantages and other features and advantages of the present invention are readily apparent from the following detailed description of the best modes for carrying out the invention when taken in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic partial cross-sectional illustration of a positive crankcase ventilation system operating with an engine assembly.

FIG. **2** is a schematic perspective view of an air-oil separator.

DETAILED DESCRIPTION

Referring to the drawings, wherein like reference numerals are used to identify like or identical components in the various views, FIG. **1** schematically illustrates an engine assembly **10** including both an engine **12** and an intake assembly **14**. The intake assembly **14** may include, for example, an air cleaner assembly **16**, a throttle **18**, and an intake manifold **20** disposed in a series arrangement. The throttle **18** may be disposed between the air cleaner assembly **16** and the intake manifold **20**, and may be configured to selectively restrict the flow of air **22** into the intake manifold **20**. The air cleaner assembly **16** may include housings, ports, and/or conduit that may be located upstream of the throttle **18**. In one configuration, the air cleaner assembly **16** may include, for example, an air filter **24** with a sufficient porosity or other construction to filter airborne debris from the intake air **22** prior to its passage into the intake manifold **20**.

The engine **12** may include an engine block **30**, a cylinder head **32**, an oil pan **34**, and an engine cylinder head cover **36**. The engine block **30** may define a plurality of cylinder bores **38** (one of which is shown), with each cylinder bore **38** having a reciprocating piston **40** disposed therein. The plurality of cylinder bores **38** may be arranged in any suitable manner, such as, without limitation, a V-engine arrangement, an inline engine arrangement, and a horizontally opposed engine arrangement, as well as using both overhead cam and cam-in-block configurations.

The cylinder head **32**, engine block **30**, and reciprocating piston **40** may cooperate to define a combustion chamber **42** for each respective cylinder bore **38**. Additionally, the cylinder head **32** may provide one or more intake passages **44** and exhaust passages **46** in selective fluid communication with the combustion chamber **42**. The intake passage **44** may be used to deliver an air/fuel mixture to the combustion chamber **42** from the intake manifold **20**. Following combustion of the air/fuel mixture (such as when ignited by a spark from a spark plug **48**), the exhaust passage **46** may carry exhaust gasses out of the combustion chamber **42**.

During engine operation, an intake stroke of the piston **40** may draw intake air **22** through the air cleaner assembly **16**, past the throttle **18**, through the intake manifold **20** and intake passage **44**, and into the combustion chamber **42**, where fuel may be introduced via fuel injectors (not shown). During the power stroke of the piston **40**, following the ignition of the air/fuel mixture in the combustion chamber **42**, a portion of the combustion gas may pass between the piston **40** and the engine block **30** (i.e., blowby gas **50**) and into the crankcase volume **52** (the crankcase volume **52** being generally defined by the engine **12** via the oil pan **34** and engine block **30**). Because the blowby gas **50** includes an amount of un-burnt fuel and products of combustion (such as water vapor), it may be desirable to avoid having these gasses accumulate within the crankcase volume **52**. Accordingly, a positive crankcase ventilation system (PCV system) may be used to purge the blowby gas **50** from the crankcase volume **52**.

The PCV system may utilize ducting, passageways, and/or volumes that may actively vent the blowby gas **50** from the crankcase volume **52** into the intake system **14** where it may eventually be exhausted via the exhaust passage **46**. More specifically, the PCV system may include a first fluid passageway/conduit **60** that may fluidly couple the crankcase volume **52** with a volume **62** defined by the cylinder head cover **36** (i.e., the "camshaft volume **62**"). As may be appreciated, the camshaft volume **62** may contain one or more rotating camshafts **64** that are configured to translate one or more valves.

Adjacent to the camshaft volume **62**, the PCV system may include an air-oil separator **66** that generally defines a separator volume **68**. In one configuration, the separator volume **68** may be fluidly coupled with the camshaft volume **62** through a plurality of ports **70**. The separator volume **68** may be fluidly coupled with the intake manifold **20** through a second fluid conduit **72**. Additionally, the crankcase volume **52** may be coupled with the air cleaner assembly **16** through a third fluid conduit **74**. Depending on the configuration of the engine **12**, the first fluid conduit **60** may be, for example, a bore or channel within the engine **12**, or may be, for example, a tube that extends between the crankcase volume **52** and the separator **66**.

During normal operation (excluding wide-open throttle scenarios), the intake stroke of the engine **12** may generate a vacuum in the intake manifold **20** as a result of the throttle **18** partially blocking the intake air flow **22**. This vacuum may draw the blowby gas **50** from the crankcase volume **52** through both the camshaft volume **62** and the separator volume **68** and into the intake manifold **20** via the first and second fluid conduits **60**, **72**. A portion of the air used to dilute the blowby gas **50** may be supplied via the third fluid conduit **74**, which may be coupled to the air cleaner assembly **16** upstream of the throttle **18**. As such, the pressure differential across the throttle **18** may generate a motive force that may actively vent the crankcase volume **52**. One or more nozzles, restrictor orifices, or valves **80** may be positioned in line with the second fluid conduit **72** to provide generally constant flow under various engine operating conditions. Likewise, a check valve **82** may be positioned in line with the third fluid conduit **74** to prevent back flow from the crankcase volume **52** to the air cleaner assembly **16**.

Due to engine vibrations, motion of the vehicle, the reciprocal motion of the piston **40**, and/or the rotating motion of the crankshaft **90**, oil **92** contained within the crankcase volume **52** may be splashed, foamed, atomized, misted and/or sprayed within the entire crankcase volume **52**. The atomized/particulated oil, along with the intake air **22** and blowby gas **50**, may then be drawn out of the crankcase volume **52**, into the camshaft volume **62**, via the first fluid conduit **60**. While the atomized oil may be beneficial within the camshaft volume **62** to lubricate various moving parts (including the rotating camshafts **64**), it is desirable to extract as much oil **92** as possible from the blowby gas **50** before the gas **50** passes into the intake system **14** and combustion chamber **42**.

FIG. **2** illustrates one embodiment of an air-oil separator **66** that may be used with the present engine assembly **10**. As shown, an internal surface **100** of the separator **66** may generally define the separator volume **68**. The separator may include a plurality of inlet ports **70** in fluid communication with the crankcase volume **52** and/or camshaft volume **62**, and may include one or more outlet ports **102** in communication with the intake system **14**. A cover **110** may be disposed over the illustrated portion of the air-oil separator **66** to form a substantially closed channel between the inlet ports **70** and outlet port **102**. Additionally, one or more gravity fed drains **104** may be in communication with the separator volume **68**, and may allow separated oil **92** to flow out of the air-oil separator **66**, and back to the crankcase **52**.

To facilitate the run off of oil **92** to the drain **104**, when installed with the engine **10** (i.e., in a operational position within the vehicle) the air-oil separator **66** may be disposed at an angle of inclination **106** relative to horizontal **108** ("horizontal" being defined as a plane that is orthogonal to a gravity force vector). Such an arrangement may include the air-oil separator **66** being disposed within a cylinder head cover of a V-type engine arrangement (i.e., where two banks of engine cylinders are disposed at an angle relative to each other).

To accomplish the desired oil-extraction, the separator volume **68** may be specially configured to separate and remove oil **92** from the flowing blowby gas **50** and allow the oil **92** to drain back into the crankcase volume **52**. For example, the separator **66** may include one or more baffles (e.g., baffle **94**), fins, or restrictions extending into the separator volume **68** that may aid in separating the oil from the air. These features may aid oil extraction through, for example, flow redirection or by creating a varying pressure along the flow path.

As generally illustrated in FIG. **2**, in one configuration, a baffle **94** may define a plurality of holes **112** through which the blowby gas **50** must pass. The pressure differential across the baffle/holes **94**, **112** may cause any suspended oil **92** to atomize/mist upon exiting the baffle, which may promote ultimate separation. Likewise, inertia of the particulated oil **92** may cause the oil to collide with one of the baffles **94** or internal surfaces **100** of the separator **60**. Once in contact with the wall, the surface tension of the oil **92** may cause it to cling to the surface **100**, where it may subsequently run off (via gravity) toward the drain **104**.

It has been found that the efficiency of the air-oil separator **66** is increased when the internal surface **100** is wetted with oil **92**. It is contemplated that the wetting promotes greater cohesion between the oil aerosol and the wall than a non-wetted surface would. Experimental testing has proven this improvement by witnessing an increase in separator efficiency over time, and by comparing an initially wetted separator with an initially dry separator. The difficulty, however, is that once the engine **10** is off for a prolonged period of time, any wetting oil will have a tendency to drain out of the separator **66**.

Therefore, as further illustrated in FIG. **2**, the interior surface **100** may include a plurality of depressions **120** that are each configured to hold a volume of oil during normal operation (i.e., each respective depression **120** is configured to restrain the respective oil from freely flowing to the drain **104**). In this manner, by retaining oil in each of the respective depressions **120**, the interior surface **100** may maintain a minimum surface wetness equal to the total surface area of all of the plurality of depressions **120**.

In one configuration, each depression **120** may be formed using a stamping die at the same time the remainder of the air-oil separator **66** is formed (assuming a metal construction). Alternatively, each depression **120** may be molded in place during an injection molding process to form the remainder of the air-oil separator **66** (assuming a polymeric construction). For simplicity in manufacturing, each depression may have a generally spherical or generally ellipsoid-like surface profile. In either instance, the average diameter may be between approximately 1 mm and approximately 10 mm. In other configurations, different depression-profiles may be used, for example and without limitation, cubic depression-profiles and/or conical depression-profiles. As may be appreciated, the plurality of depressions **120** must be disposed on a surface that is intended to face substantially downward following final installation in the vehicle. Likewise, the angle of inclination **106** may be less than approximately 60 degrees so that each of the respective depressions may be capable of retaining its respective volume of oil, while also restraining that oil from freely flowing to the drain.

While the best modes for carrying out the invention have been described in detail, those familiar with the art to which this invention relates will recognize various alternative designs and embodiments for practicing the invention within the scope of the appended claims. All directional references (e.g., upper, lower, upward, downward, left, right, leftward, rightward, above, below, vertical, and horizontal) are only used for identification purposes to aid the reader's understanding of the present invention, and do not create limitations, particularly as to the position, orientation, or use of the invention. It is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative only and not as limiting.

The invention claimed is:

1. An engine assembly comprising:

an engine defining a combustion chamber and a crankcase;

an intake assembly including an intake manifold, the intake manifold being in fluid communication with the combustion chamber; and

an air-oil separator defining a separator volume and further defining an inlet and outlet in fluid communication with the separator volume, the inlet of the air-oil separator being in fluid communication with the crankcase, and the outlet of the air-oil separator being in fluid communication with the intake manifold;

wherein the air-oil separator includes an interior surface that abuts and surrounds substantially the entire separator volume; and

wherein the interior surface of the air-oil separator forms a plurality of depressions on the interior surface, each being configured to continuously contain a respective volume of fluid when the engine is both operating and not operating.

2. The engine assembly of claim **1**, wherein the air-oil separator includes a drain; and

wherein each of the plurality of depressions is configured to restrain its respective volume of fluid from freely flowing to the drain.

3. The engine assembly of claim **1**, wherein the air-oil separator further includes a baffle extending from the interior surface into the separator volume.

4. The engine assembly of claim **3**, wherein the baffle defines a plurality of holes.

5. The engine assembly of claim **1**, wherein the engine includes an engine block, a cylinder head, an oil pan, and a cylinder head cover; and

wherein the air-oil separator is disposed within a volume partially defined by the cylinder head and cylinder head cover.

6. The engine assembly of claim **1**, wherein each of the plurality of depressions are respectively configured to continuously contain a volume of fluid to maintain a minimum average surface wetness across the interior surface of the air-oil separator.

7. The engine assembly of claim **1**, wherein the intake assembly includes a throttle in communication with the intake manifold; and

wherein the throttle is configured to selectively control air flow into the intake manifold.

8. The engine assembly of claim **1**, wherein each of the plurality of depressions has an average diameter between 1 mm and 10 mm.

9. A method of separating oil from engine blowby gas comprising:

venting blowby gas from the crankcase of an engine into an air-oil separator;

flowing the blowby gas through a separator volume defined by the air-oil separator, the air-oil separator having an interior surface abutting and surrounding substantially the entire separator volume; and

venting the blowby gas from the separator volume into an intake manifold of the engine; and

wherein the interior surface of the air-oil separator forms a plurality of depressions on the interior surface, each being configured to continuously contain a respective volume of fluid when the engine is both operating and not operating.

10. The method of claim **9**, further comprising restraining a fluid disposed in each of the plurality of depressions from freely flowing to a drain.

11. The method of claim **9**, wherein each of the plurality of depressions has an average diameter between 1 mm and 10 mm.

12. The method of claim **9**, wherein the engine includes an engine block, a cylinder head, an oil pan, and a cylinder head cover; and

wherein venting blowby gas from the crankcase of an engine into an air-oil separator includes passing the blowby gas through the cylinder head.

13. The method of claim **9**, wherein the engine includes an engine block, a cylinder head, an oil pan, and a cylinder head cover; and

wherein the air-oil separator is disposed within a volume partially defined by the cylinder head and cylinder head cover.

14. An engine assembly comprising:

an engine including an engine block, a cylinder head, an oil pan, and a cylinder head cover, the engine block and oil pan partially defining a crankcase;

an intake assembly including an intake manifold, the intake manifold being in fluid communication with the combustion chamber; and

an air-oil separator defining a separator volume and further defining an inlet and outlet in fluid communication with the separator volume, the inlet of the air-oil separator being in fluid communication with the crankcase via the cylinder head, and the outlet of the air-oil separator being in fluid communication with the intake manifold; and

wherein the air-oil separator includes an interior surface that abuts and surrounds substantially the entire separator volume; and

wherein the interior surface of the air-oil separator forms a plurality of depressions on the interior surface, each being configured to continuously contain a respective volume of fluid when the engine is both operating and not operating.

15. The engine assembly of claim **14**, further comprising a fluid conduit extending between the intake assembly and the crankcase, the fluid conduit operative to allow air to pass from the intake assembly into the crankcase.

16. The engine assembly of claim 15, wherein the fluid conduit includes a check valve operative to restrict air from passing from the crankcase into the intake assembly.

17. The engine assembly of claim 14, wherein each of the plurality of depressions has an average diameter between 1 mm and 10 mm.

18. The engine assembly of claim 14, wherein the air-oil separator includes a drain; and

wherein each of the plurality of depressions is configured to restrain its respective volume of fluid from freely flowing to the drain.

19. The engine assembly of claim 14, wherein the air-oil separator further includes a baffle extending from the interior surface into the separator volume.

20. The engine assembly of claim 19, wherein the baffle defines a plurality of holes.

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